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Published in:
eCAADe RIS 2019. Virtually Real. Immersing into the Unbuilt

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Publication date:
2019

Document Version
Publisher's PDF, also known as Version of record

[Link to publication from Aalborg University](#)

Citation for published version (APA):
Vistisen, P., Luciani, D., & Ekströmer, P. (2019). Sketching Immersive Information Spaces: Lessons learned from experiments in 'sketching for and through virtual reality'. In N. Steinø, & M. Kraus (Eds.), *eCAADe RIS 2019. Virtually Real. Immersing into the Unbuilt: Proceedings of the 7th Regional International Symposium on Education and Research in Computer Aided Architectural Design in Europe* (pp. 25-36). Aalborg Universitetsforlag.

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Sketching Immersive Information Spaces

Lessons learned from experiments in 'sketching for and through virtual reality'

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This paper presents the lessons learned from a design workshop exploring methods for early exploration of immersive information spaces, such as Virtual Reality (VR). The methods explored cover design situations both designing for VR, and designing through VR, in varying degrees of fidelity. The workshops shared the common factor of attempting to enable a feedback loop between sketching activities and the more didactic and time consuming prototyping processes. From our analysis, we found that to achieve true 'sketchiness' in an immersive VR settings, tool proficiency naturally becomes a decisive factor, since a lot of new techniques needs to be learned and gained experience with. Furthermore, it is evident that the mental shift, from flat to 360 degree design, was challenging, but also the enabler of new creative constraints from which the designer can explore the boundaries of the design space. We conclude by arguing for the development of more formalized patterns, materials and tools to not just enable immersive sketching, but also enable grasping the immersive design space itself by motivating the explorations and happy accidents when 'doodling' in the immersive space.

Keywords: *sketching, virtual reality, prototyping, animation-based sketching, immersive information spaces*

INTRODUCTION

When designing immersive information spaces, understood as the conjunction between a physical presence, and a virtual layer of digital information, traditional design tools, such as scenarios, personas, and mockups, are generally not enough to capture and sufficiently explore the intended user experience of the design proposal (Jerald 2016). This aspect is true both in terms of the feedback loop of the individ-

ual designers iterative 'design moves' during exploration (e.g. Schön in Winograd 1996) and in terms of sharing and critiquing the design proposal amongst design peers, because of the abstract nature of the combined virtual and physical design space. In recent years, this problematic area of design has seen an increased attention mainly due to the maturity of Virtual Reality (VR) technologies now being available on consumer and prosumer level, expanding the

use cases and portfolio of applied cases for both designing for, and designing through immersive digital spaces. This extends from broadly oriented consumers appliances in entertainment and games (e.g. Pallavicini et al 2017, Rosa et al 2016), to more specialized professional use cases in e.g. surgical training (Huber et al 2017), manufacturing (Seth et al 2010), industrial design (Berg & Vance 2017), and architecture (Portman et al 2015). Despite these recent developments in design applications for VR, there still seems to exist a barrier for how to use it in the early idea stages of design. Traditionally, these stages are defined by various interpretations and manifestations of 'design sketching' (e.g. Verstijnen et al 1998, Goldschmidt 1994, Buxton 2010). In sketching, the ideation is informed by creating rapid, evocative, and non-didactic outputs - as opposed to the definitive nature of prototypes (Buxton 2010). But the perhaps most important aspect of design sketches is their disposable nature - they are plentiful, and created through a fast feedback loop of reflection in and on action (Schön in Winograd 1996), where the ideas should be allowed to perish as fast as they were created. This sketching feedback loop is still a challenge when working with immersive technologies like VR. It could be argued that when applied to display an architectural CAD drawing through an immersive 360 degree perspective (Portman et al 2015), the mere act of viewing a CAD 'sketch' in VR is a natural extension of the sketching feedback loop. However, we argue that this feedback loop could be brought earlier in the design process, to the steps before computational tools like CAD software. This is due to the nature of computerized design tools, which are somewhat already constrained by their own didactic procedures, and thus less 'sketchy' than e.g. the early hand-drawn sketches or physical mockups, made by the designer before having any firm grasp of the design problem at hand. In the study presented in this paper, we set out to explore how 'sketchy' feedback loops could be achieved when exploring immersive design concepts in VR settings - both when designing for VR, and when designing through VR. The pa-

per details the findings from a series of design workshops, exploring various techniques and methods for sketching and prototyping immersive information spaces aimed for VR. Below we briefly introduce the sketching and prototyping approaches we based these studies upon, before introducing the findings from the workshop.

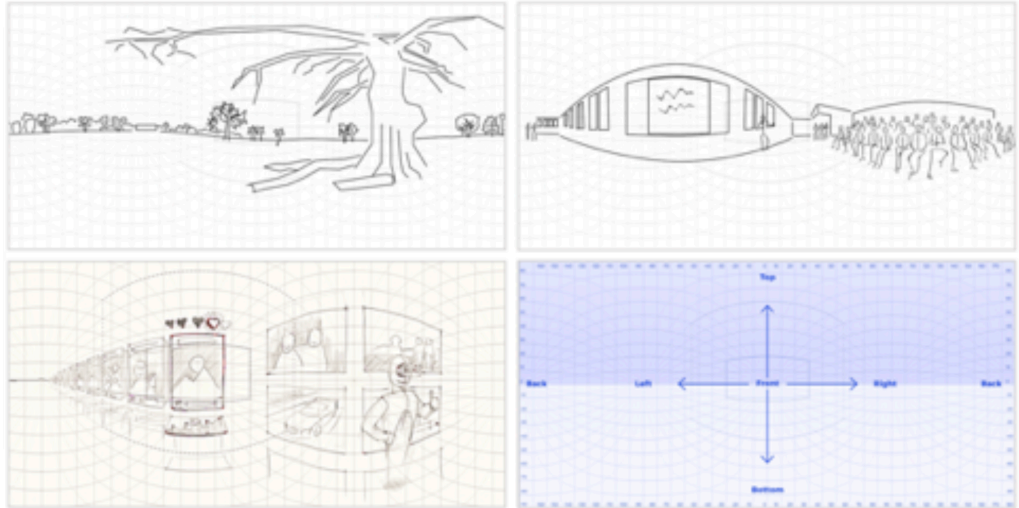
IMMERSIVE SKETCHING AND PROTOTYPING

One emerging approach for bringing hand-drawn sketches into a VR environment is the use of equirectangular coordinate systems (the same format used on a traditional world map). Here, a 360 degree map is flattened and distorted to fit a 2D surface. The quality of these 2D representations are that, if drawn correctly and taking the distorted perspective into consideration, the output image will be non-distorted in a VR environment from a first person point of view. A few examples of equirectangular sketches are shown in Fig 1 as well as a guiding grid made for sketching.

Equirectangular sketches - the pen-and-paper of immersive sketching?

Sketching in a equirectangular coordinate system requires the designer to think of traditional straight lines as curves, and divide the sketching canvas into 'field of views' where the middle of the paper is the front view, and the left, right, top, and bottom corresponds to looking to the sides as well as up and down. This requires the designer to rethink the dimensional space of the paper, where specific regions are more distorted than others. But in its premise, equirectangular grids is an attempt to transfer the principles inherent to traditional design sketching as a way of doing 'visual thinking' (Suwa & Tversky 1997, Goldschmidt 1994, Schön & Wiggins 1992), mimicking the immediate feedback loop of expressing a design move, seeing and reflecting on the depicted, and then make a new design move as a response to how the sketch was 'read'. Equirectangular sketching shares many qualities of pen and paper, but lacks one crucial aspect in regard to the visual thinking

Figure 1
Examples of
sketches made in
the equirectangular
coordinate system,
with the our
designed guiding
grid to the lower
right.



of sketching: the immediate feedback loop. While the designer can immediately see the specific strokes and changes made in the equirectangular grid, the impact of the sketching move on the immersive information space depicted is first realised when the paper is copied into a supported viewing platform. This process can be done rather quickly, with only few seconds between scanning the paper and seeing the response digitally in 360 degree. However, this also brings a certain amount of finality to the sketch output being scanned and viewed in 360 degree since the designers has to assess the sketch is now 'ready' to be explored as immersive space, and not just as flat equirectangular representation. This brings the danger of putting too much effort into the sketch, defeating the purpose of sketches being timely, disposable and non-committable (Buxton 2010). As such, the equirectangular sketches are at risk of not being ambiguous enough to "...leave big enough holes for interpretation" (Buxton 2010, 115). The equirectangular sketching approach may thus act as way for the designer to explore their concepts on paper in one prolonged sketching move, before reflecting on the

output and letting others experience and critique it through the immersive viewing medium later on.

Temporal sketches as a middle ground

Another potential sketching method for immersive technologies is temporal sketching approaches, such as video sketching (Tikkanen, T., Cabrera, AB. 2008), and animation-based sketching (Vistisen 2016, Tran Luciani & Vistisen 2017). This approach also challenges what can be considered sketching. Regardless of whether the temporal sketch is based on simple stop motion effects or edited motion graphics, the process of making a design move, reflecting upon it, and then making a concurrent move is challenged since the digital medium requires the designer to determine more aspects in their head, before expressing it visually. Temporal sketching mostly lack the immersive viewing, since most video and animation-based sketches tend to be narrative scenarios shown from a linear structured perspective. While it is possible to simulate e.g. a first person VR view through graphic masking overlays, it will still only mimic the immersive 360 degree space, and not enable the de-

signer, or other stakeholders, to assess the immersive aspects in detail, but rather assess the scenario as a whole user journey. However, with recent developments in digital authoring tools, the possibilities to actively create, edit and live-preview changes made to e.g. 360 degree footage and imagery has shown potential to actually enable true digital sketching in a live updated 360 degree preview inside software such as Adobe Premiere and Adobe After Effects. This would blur the lines between temporal sketching, which tends to be linear, and immersive sketching, which needs some degree of user interaction, positioning itself along contemporary contributions on using video and animation in sketching (e.g. Vistisen 2016, Löwgren 2004, Fallman, D. & Moussette, 2011). These new emerging uses of the software was thus our state of art in how temporal sketching was applied and introduced in the workshops for this study.

VR sketching - true immersive sketching

The potential to use VR as a sketching/prototyping tool has long been recognized by the literature, but while there have been several studies detailing the development of tools for VR sketching and modelling (e.g. Fiorentino, De Amicis, Monno, & Stork, 2002; Schkolne, Pruett, & Schröder, 2001; Jackson & Keefe, 2006; Barrera Machuca, Asente, Lu, Kim, & Stuerzlinger, 2017), there is a lack of literature about the process of sketching through VR and reflection on the use of currently available tools. Using VR tools as sketching media for early design has several potential benefits, such as spatiality, allowing the designer to walk into the sketch, one-to-one proportions, association, using existing objects as references in the environment and formability (Israel, Wiese, Mateescu, Zöllner & Stark, 2009). The immersive experience of VR sketching also allows our bodies to be part of the design process, making it possible to use them as reference and consider ergonomics early in the design process. Moreover, VR interaction allows the designers to use their hands directly in the creation process (Petrov, 2018). A recent

study on VR and creativity by Yang et al. (2018) suggests that immersive VR helps to maintain a more stable focus and enables a better state of flow, which results in a greater creativity performance. The study compared the creative output in immersive VR using 'Tilt Brush' and traditional pen-and-paper-sketches. While the participants in the study were only allowed 5 minutes to design their product in respective media, the results suggest that the immersive VR environment stimulated novel ideas and inspired the participants to be free from past ideas. Similarly, Keeley (2018) studied 19 second year students using VR sketching tool 'Tilt Brush' to explore how VR sketching impacts on the designer's ability to produce concepts and communicate them in conceptual design. The post-use questionnaires and focus groups revealed that the students thought that VR sketching improved their creativity and their ability to communicate. The latter was because they could easier analyze their objects in 3D space instead of on a flat paper. They also suggested that VR gave them a better sense of scale, especially with larger products. Moreover, when observing the students, Keeley (2018) noted that the immersive nature of VR sketching allowed the creation of concepts from the user's point-of-view, such as making a sleeping bag by lying down and drawing it from the inside.

DESIGN WORKSHOPS

The design workshops were a core part of a studio-based course in immersive information spaces held at Linköping University. During a period of three months in fall 2018, seminars and design workshops were given with the goal for students to develop proficiency exploring innovative concepts for immersive spaces, like VR. The design workshops were practical learning activities focused on techniques for designing and exploring individual concepts for an immersive space. While all students chose to use VR as their final medium, various types of sketches were produced along the way. Some immersive concepts were explored through 2D sketching tools, which we label 'sketching for VR', while others were being cre-

ated in the 3D immersive environment, which we label 'sketching through VR'. The design workshops were divided into two parts to introduce tools and techniques to enable sketching for VR and sketching through VR respectively. We, the authors, were facilitators at the workshops and gathered data through observations and field notes. We also collected the students' produced materials such as work-in-progress sketches, final sketches, and their own written reflections. The data was used to examine and analyze the design process of their concept development. We examined the design process of six of the students with explicit consent, all accordingly to the GDPR regulations. They were all second-year students at the same Design master program, but had backgrounds in various different design domains such as graphic design, web design, and product design. Through previous project works within the program they had all been exposed to sketching and prototyping approaches, but they were all novices with regards to VR. This particular course in immersive information spaces focused even more on the explorative aspects, giving the students the opportunity to further develop their sketching mind-set. In the analysis we have arranged the cases into a series of induced themes for which the included case is exemplary of - not necessarily presenting each case in its full extent, but comparing and including different cases under the same theme.

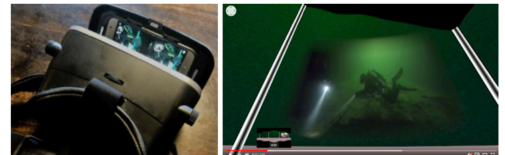
INSIGHTS FROM THE DESIGN WORKSHOPS

In this section we show selected examples from the two workshops highlighting lessons learned about sketching and prototyping when designing immersive information spaces.

From idea to sketch to prototype - a horizontal slice of applied methods

A project concerned with designing a virtual underwater exhibition about historical shipwrecks was an example of a horizontal slice of all introduced methods from the workshops. The student initially

sought to convert flat graphics into equirectangular images digitally, but quickly realised an issue of non-panoramic graphics distorting heavily when adjusted to an equirectangular grid. Instead, the student experimented with mocking up an equirectangular landscape of graphics in the grid. Afterwards, the student took the experiment into VR and explored the consequences of the arrangement. An expected next 'sketching move' would have been to make adjustments to the design (a refinement) or make a new version based on the reflection from seeing the sketch in VR (an iteration). However, the student expressed that this sketch was only an experiment which "...enhanced the level of immersion and understanding of how the final VR experience might feel". As such, the equirectangular graphics were not a concept on itself, but rather an 'investigation' of the design space, rather than a conceptual 'explorative' sketch (see Olofsson & Sjölen 2007). This inquiry into the design space is akin to traditional rough doodles exploring the design space, but with little direction towards true ideation of new solutions.



This led the student to actively direct his efforts in using the equirectangular guiding grid as the basis for sketching his new concept idea of a 'virtual diving cage', effectively taking inspiration from the prior sketch, but now with considerations about what the user could experience and interact with the immersive experience. This process took place inside Adobe Premiere, with the possibility to get immediate feedback through live-rendering and the built-in 360 degree viewer, allowing for explorative sketching moves, where the student both refined and made different iterations of the diving cage concept. The student also tried to transfer his sketching process to the VR design applications 'Masterpiece VR' and 'Tilt Brush' to experiment with not just sketching for

Figure 2
Examples of the immersive sketches and prototypes made of the 'virtual diving cage' concept. The first equirectangular investigation of design space in a VR viewer (left), and the first refined conceptual exploration of the experience of a diving cage (right).

VR, but directly through VR. While this provided the benefit of not having to make the mental translation from equirectangular depiction to 360 degree viewer, these tools also presented both some practical and ergonomic challenges for the sketching process. A practical challenge was how these immersive VR applications were “...constrained to one room and as far as we saw, there was no way of creating several scenes and jump between them”. This was opposed to the relative freedom of expression experienced with the equirectangular sketches, which were challenging to get an initial grasp upon, but offered more versatility. The student used the VR application ‘Storyboard VR’, and transcended into trying to make a more refined version of the diving cage concept, coming closer to the look and feel of the concept’s visual design and interactions. This tool use was thus more akin to the resolving and specific nature of prototyping, seeking to narrow down choices in the design space rather than diverging towards exploring new directions. Here, the student experienced the benefit of having sketched digitally inside Adobe Premiere earlier, since the digital assets could be transferred directly into ‘Storyboard VR’ - essentially enabling a transition between sketching and prototyping without turning to a new ‘material’. What was obtained was a more true immersive response due to the VR applications ability to provide not just 360 degree orientation, but also parallaxed depth. The details being explored was seen adding a significant progress towards asking specific questions of e.g. how a user should interact when facing a specific part of the experience. The application thus promoted the creation of more detailed assets in traditional 2D design software, and arranging them in VR afterwards. As such, the student did not make gradual sketching loops anymore, but rather specified the details of his design prior to prototyping the exact scene in the software. Some iterations did appear, in regards to how to arrange the pre-produced elements, with new ideas about e.g. the design of graphical overlays on the underwater setup arising from seeing the placement live in the VR environ-

ment. This shows that even when prototyping, the need to explore and immerse yourself as designer into the VR design space also fosters ‘sketchy’ behaviour - even though the assets used are premade outside the VR setting.



However, a significant drawback experienced while using ‘Storyboard VR’ was that although the experience is immersive, there is no way to add real interactivity. While the application lets the user create more ‘scenes’ and flip between them like a storyboard, the lack of more elaborate user interactions with e.g. virtual elements was experienced as a barrier to move the prototyping further. This prompted the student to apply temporal video- and animation-based sketching methods. Initially this was introduced as a ‘middle ground’ between the equirectangular sketching and the VR applications used for prototyping. But in this case, the student needed a more free form to further develop his prototype in terms of exploring the interaction design, but also to think about the entire scenario of the proposed concept as a whole. The student thus combined graphical elements made for both the equirectangular sketches and ‘Storyboard VR’ and edited them together in Adobe Premiere, adding masking overlay to simulate the edges of a head-mounted display. Inside this simulated field of view, the student animated a virtual hand interacting with the shipwreck and other items from within the diving cage. Other graphical elements, such as video and text annotations, were gradually added to create a complete concept for the interaction, and the resulting informations shown to the user. Finally the student created an animated video scene from outside the VR environment, showcasing some contextual considerations for what would happen before and after the VR experience itself.

Figure 3
The arrangement of previous designed graphical elements in underwater backdrop in ‘Storyboard VR’ (left), and an example of the student attempting to design user interfaces and simulate an interaction in the application (right).

Figure 4
The final temporal sketches made to simulate interactivity from 1st person (left), and the overview of the pre-experience context of the VR application (right).



In this instance, what we thought would be a middle ground turned out to be the last step of the process - adding contextual details and narrative flow to the entire user experience of the proposed immersive concept as a whole. The temporal mediums were limited in terms of enabling true immersive VR exploration, but enabled the combination of many different types of visual materials to simulate the specific features the students lacked the ability to express through VR. Interestingly, almost all projects applying the temporal methods choose to show a bit of the context of use through these techniques, emphasizing the importance of not just thinking of the sketching for the immersion of the concept alone, but also address the 'before' and 'after'. Again, the temporal applications were assessed to have their own limitations, mainly that they had to be 'hacked' to work well for design sketching, and not just for traditional video editing. Furthermore, the static nature of video also left the students with questions still unanswered about the possible use cases which might arise with their concepts - not easily testable without realising full functionality in VR.

Sketching as doodling - building a sketching literacy for a new medium

Doodling in traditional sketching is method of letting the pen go and seeing what happens. Doodling is without goal and intention, but as the designer doodles, at any time there might be a "happy accident" which sparks a direction for more intentional sketching. This doodling mindset can also be used when exploring a concept in a new medium, as experimenting with the tool's capabilities and how it can be used is as much an exploration of the medium as the concept itself. One student experienced a turning moment in the process when she let the VR tool direct her in her concept development, explor-

ing and experimenting with the assets and functionality that were available in the tool instead of trying to force it to do what she had in mind. Another student was initially frustrated with the interaction space limits in VR, describing how she often got lost in the virtual world and ended "bumping into" the edges of the interaction space, seeing the blue grid signifying that a physical barrier is close by. However, when she decided to make use of the limitations, it inspired her to create an interaction concept where she took away the ability to teleport around in the virtual world and used the limited space as a way to convey the powerlessness of not being able to walk away when subjected to the racial injustice in her interaction concept. Thus, exploring the limitations of the software presented new creative constraints of 'being boxed in' which developed the concept even further; exploring the medium and tool became integrated into the sketching loop itself. Both of these examples could be thought of as a conversation with the sketching tool and not just with the sketch. By letting the affordances of the tool guide them, they set themselves up for "accidental discoveries" and used the limitation of the tools as a creative input rather than a hindrance.



Figure 5
Stills from the immersive experience of being subjected to racism. The top left image shows the first scene, a park where police radio sound clips are played in the background. The other three pictures show the second scene, a convenience store where a person is following you and looking at you from behind shelves, with a heartbeat sound playing as the person gets closer.

Throughout the course, we noted that the students struggled to sketch exploratory. Many were focused on communicating a concept that they imagined in their own head and got frustrated that they were not proficient enough to use the tools and techniques in a "sketchy way". One student expressed that she "wasted a day" with the equirectangular grid. Another felt that she could not express what she was

imagining in her head and complained that “because I don’t know the tool [...] I just do what the tool can make”. Because of the difficulties to use the non-idiomatic sketching tools, they felt that they invested so much in each “sketch” that they were not actually making idea sketches, as they were neither disposable, plentiful or quick. Thus, while we have used the term “sketching tool”, the insights suggest that the tools do not allow sketching straight “out of the box”. They all need to be appropriated to accommodate sketching, especially when the medium is non-idiomatic, such as equirectangular projection, as the sketching tool will most likely also have that character.

Sketching process does not always go from low fidelity to higher fidelity

In most traditional design processes, concept development tends to progress from using low fidelity (lo-fi) tools to create sketches, such as analogue hand-drawn sketches, to higher fidelity (hi-fi) tools to create prototypes, such as physical mockups and digital CAD models. Even though we organized the workshops to mirror this tradition by starting with lo-fi tools before the sessions with hi-fi tools, the students were free to choose what techniques and tools to use for their individual projects. Analyzing the students’ design processes after the fact shows that starting with lo-fi before moving on to hi-fi tools and techniques is not always the preferred way when sketching for VR. Some students even found lo-fi tools irrelevant and “useless” for sketching their VR concept and felt the need to immediately experience firsthand the non-idiomatic aspects of VR. “I think the 3D sketching tools were more beneficial [...] because you are able to create and experience this scene by yourself. This I considered as a major learning: it helps immensely to just immerse yourself in the scene you are creating in order to develop it.” For some students it made more sense to start sketching with hi-fi tools such as ‘Storyboard VR’ or ‘Tilt Brush’ because they are used more like traditional tools that the students already were familiar with, compared to animation-

based sketches using lo-fi tools such as an equirectangular sketches and rough animations, which requires a completely different skillset. “While using Storyboard VR was entirely new to me it allowed me to create experiences inside of it with knowledge that I already had.” Despite the advantages hi-fi tools seemed to have, it does not make lo-fi tools redundant in the process of sketching for VR. The outcome of using hi-fi tools easily becomes too detailed which could cloud the purpose of sketching. “In my concept video [...] trying two different methods, both of which looked rather sketchy [...] Being able to move assets inside the 3D space sort of like how objects behave in a design program like Illustrator or Photoshop would make for an extremely precise and better workflow.” In other words, using hi-fi tools can unfortunately invite someone to get focused on details too early in the explorative process and prohibit a quick and sketchy approach. Another reason why sketching directly through VR may not always be preferred is the risk of cybersickness, i.e. motion sickness felt in VR. While this is a well-known challenge when using VR applications (LaViola 2000), the issue seems to be heavier represented with VR applications that are not just delivering a specific predefined streamlined experience. This might be due to the often quick and unnatural movements and positions needed to e.g. sketch a detail underneath an object made in ‘Tilt Brush’, which might increase the risk of experiencing cybersickness. The issue of cybersickness was clearly articulated as an issue holding the students back in fully realizing valuable sketching loops through the use of VR applications. Two of the six students experienced major cybersickness in the sense that it actually hindered their work process. One of the students took a pill against seasickness in an attempt to overcome the cybersickness, but unfortunately it did not help. In order to minimize their time spent in VR, the students found alternative ways of preparing assets at a computer, for example by using ‘SketchUp’ that they could import into a VR-app such as ‘Tilt Brush’ to test and tweak scale and position. It all comes down to picking the right tool for the task based on the

purpose of the sketching activity and the individual's skills and abilities or limitations. As with most design projects some students experienced or noted that it was beneficial to take an iterative approach moving between lo-fi and hi-fi tools, but the fidelity of the tool or produced result does not necessarily reflect whether it is a sketch or a prototype.. "Sketching 2D helped me converging, while sketching 3D helped me diverging again. A reiterative rhythm that I believe would be incredibly interesting to repeat and continue".

REFLECTIONS

This paper has presented our insights into introducing immersive sketching approaches to design students with little prior experience with designing for and in virtual reality. Since the data samples are limited to the two workshops, the insights are tentative in nature and not conclusive. However, they do highlight some interesting aspects about sketching in and for immersive environments that can inform further studies and future works. A major finding might seem obvious: 3D sketching is hard to grasp. The basic ability to understand the 360 dimensionality of the VR environment showed to be the most challenging aspect for the design students. This seems like a paradox, since many of the concepts dealt with spatial aspects, and thus the 3D design space should in theory augment the design process. However, from our analysis we argue that the observed challenge to grasp the immersive design space is due to the fact that immersiveness is not a traditional aspect of sketching, but rather an aspect of much later phases in design, leading to a lacking idioms and conventions for how to actually reflect in and on action about the sketches made both for and through VR. While we observed some instances of what could be interpreted as sketching feedback loops, most of the true sketching happened either in traditional 2D mediums like pen and paper, or through simulating only one perspective of VR at a time through iterative video sketching. Where the sketchy behavior arose in the VR setting was when the tool limitations

provoked the design students to reframe their ideas to fit the technical constraints of both the authoring tool as well as the VR technology itself. We argue that this is an effect of the unconventional tools applied - even VR design tools like 'Storyboard VR' and 'Tilt Brush' are not tailored for iterative sketching, but rather for mocking up premade scenes or artistic endeavors. These unfamiliar, non-idiomatic tools make it challenging to achieve the ideal 'reflective conversation' with the material, because of a constant resistance from the design material. Since the students were unfamiliar with the tools, they had to devote a lot of time to each "sketch", which shifted the reflective conversation into an "output monologue". Thus, using non-idiomatic tools for reflective conversation probably requires higher sketching literacy to be able to sustain the "sketchy" mindset. To build sketching literacy for the new medium we found that it was beneficial to explore the tool's capabilities with a "doodling mindset", i.e. to let the affordances of the tool guide in order to have a reflective conversation with the sketching tool. That opened the mind to view unintended outcomes as "happy accidents". Immersive sketching is still in its infancy and many of our findings can potentially be dismissed as 'just being lack of design experience' with both the domain and its tools. However, both the practical issues of enabling non-interrupted sketching loops, and the ergonomics of prolonged sketching through VR without suffering from motion sickness, also points to the need of better tools for early exploration for and through VR. Our attempts with equirectangular and temporal sketching show that different needs, besides the ability to be fully immersed in VR, may arise and that the sketching environment and the literacy required to navigate these will probably need require more than one tool or one approach to fully enable immersive sketches to be done and be valuable early in the design process. Therefore, we end by arguing for the development of more formalized patterns, guideline materials and tools (e.g. equirectangular guiding grids, VR annotation tools etc.) to not just enable immersive sketch-

ing, but also enable grasping the immersive design space itself to truly achieve sketching feedback loops for VR in design.

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